

This is a repository copy of *The aquatic basis of ancient civilisations: the case of Synodontis schall and the Nile Valley*.

White Rose Research Online URL for this paper:

<https://eprints.whiterose.ac.uk/1170/>

Book Section:

Luff, R.M. and Bailey, G. orcid.org/0000-0003-2656-830X (2000) The aquatic basis of ancient civilisations: the case of Synodontis schall and the Nile Valley. In: Bailey, G., Charles, R. and Winder, N., (eds.) Human Ecodynamics. Symposia of the Association for Environmental Archaeology . Oxbow Books , pp. 100-113.

Reuse

Items deposited in White Rose Research Online are protected by copyright, with all rights reserved unless indicated otherwise. They may be downloaded and/or printed for private study, or other acts as permitted by national copyright laws. The publisher or other rights holders may allow further reproduction and re-use of the full text version. This is indicated by the licence information on the White Rose Research Online record for the item.

Takedown

If you consider content in White Rose Research Online to be in breach of UK law, please notify us by emailing eprints@whiterose.ac.uk including the URL of the record and the reason for the withdrawal request.

12. The Aquatic Basis of Ancient Civilisations: the case of *Synodontis schall* and the Nile Valley

Rosemary M. Luff and Geoff Bailey

*This chapter focuses on the role of aquatic resources in the ancient economies of the Nile Valley. We suggest that these resources have been overlooked in traditional interpretations because of a reliance on wall paintings and carvings in tombs, assumptions about the dominance of cereal crops, and a dearth of well-excavated faunal assemblages from settlement sites. We focus on the faunal material from Tell el-Amarna and in particular the fish remains, which are dominated by the catfish, *Synodontis schall*. We show that, in conjunction with the study of modern control samples, we can obtain reliable estimates of age-at-death and size from growth increments in the pectoral spines, and thus analyse the age and size distribution of fish caught and their growth rates. As might be expected, the modern *schall* populations show evidence for more intensive fishing pressure than the ancient populations. Unexpectedly, however, the Roman material suggests that *schall* were exploited more intensively than in the preceding Dynastic period, and that they suffered lower growth rates. We argue that the slower growth rates are the result of climatic deterioration in the 6th century AD, and that the increased pressure on *schall* may reflect a decline in food supplies from other sources and a need for greater reliance on the fish resources of the river.*

Keywords: FISH; GROWTH INCREMENTS; DYNASTIC; ROMAN; AMARNA; CLIMATIC CHANGE.

INTRODUCTION

It is widely assumed that the economic basis for the rise of the great riverine civilisations of the Old World was crop agriculture, and that their achievements in population growth, urbanisation, trade, socio-political organisation, monumental architecture and religion had to depend on the invention of agriculture and its subsequent diffusion outwards from a centre of origin in the Fertile Crescent. Livestock are taken for granted as complements to arable agriculture, while hunting, fishing and fowling are treated as incidental supplements. This is nowhere more so than in the case of Ancient Egypt, where the annual inundation of the Nile and its effect on soil fertility and crop productivity has dominated palaeoeconomic interpretations and resulted in an emphasis on bread and beer as the traditional economic staples.

This view of the origins of civilisations as a ladder-of-economic-progress supported by crop agriculture is so deeply embedded that it is almost unchallenged. Yet

we believe that it greatly over-emphasises the significance of cereal crops and may even be fundamentally wrong. It makes no allowance for the possibility that aquatic resources could have underwritten indigenous foundations of early social developments, and that these may already have been in place or in process before the diffusion or development of crop cultivation. Nor does it allow for the complementary role of aquatic resources alongside the domesticated crops and animals. Certainly, apart from isolated claims for the importance of marine resources in the growth of early civilisations, notably in Peru (Moseley 1975, 1992) and the Arabian peninsula (Tosi 1986), there has been little systematic investigation of alternative economic pathways to the development of ancient civilisations.

It is not our intention to discount the importance of storable surpluses supplied by cereals or the impact of the annual Nile flood on soil fertility. Our aim is rather to examine some of the biases of existing views on the

ancient Egyptian economy, to highlight the role of other resources that could have been of at least equivalent importance, and to demonstrate the value of carefully recovered archaeozoological material. We concentrate in particular on the fish remains from the site of Tell el-Amarna, and on the incremental growth structures preserved in the pectoral spines of the African catfish, *Synodontis schall*, or schall, which is the most abundant fish taxon represented in the Amarna deposits. We demonstrate that growth increments combined with size measurements allow estimates of age structure and growth rates of the exploited fish populations at different periods, and that these are a potentially sensitive indicator of wider economic conditions and of environmental and climatic change.

ASSUMPTIONS AND BIASES

Conventional views of the Ancient Egyptian economy are influenced both by assumptions about the nature of the subsistence economy, and by reliance on inadequate or biased archaeological records.

The potential of aquatic resources

Large rivers, like coastlines, can produce a concentrated abundance and variety of food resources, including fish, birds and molluscs to complement plants and animals on land, and the conventional emphasis on crop agriculture and livestock rearing pays insufficient regard to the importance of this point.

Aquatic resources occur at varying times of year, pose variable technical constraints on capture, and are subject to different sorts of environmental constraints, compared to terrestrial resources. Thus, they not only provide an additional supply of food that can raise the human carrying capacity of an area, but also play an important complementary role to plants and animals on land. Many are also amenable to simple techniques of food storage by drying, salting or fermentation and can easily be transported. They add variety to the diet, and additional supplies of essential nutrients. Adequate nutrition under intensifying crop-agriculture regimes in particular depends on a complementary supply of animal protein, whether from the meat and secondary products of domestic livestock or from fish or other natural sources of protein (Armstrong *et al.* 1984; Haas and Harrison 1977; Martin *et al.* 1989; Santley and Rose 1979). Fish in particular are an important source of protein, calcium, phosphorus and vitamins A and D, and vitamin A occurs in higher quantities in fish than in terrestrial animals (Borgstrom 1961, 412). Aquatic resources also play a vitally important role in tiding over periods of food shortage caused by such factors as harvest failure, spoilage of grain stores and livestock disease.

The fish fauna of the Nile drainage is one of the largest in Africa with 115 taxa, of which 26 are endemic

(Greenwood 1976). Many of the 47 commercial taxa which inhabited the river in Egypt in 1948 have disappeared (Said 1994). Pollution is a problem and lead-contaminated fish from the Nile near Assiut in Middle Egypt have been shown to exceed the maximum recommended safe levels for daily human consumption (Seddek *et al.* 1996; WHO 1972). Some 17 taxa are now caught in Upper Egypt today. *Tilapia nilotica* accounts for about 60 per cent of the total commercial catch, which also includes catfish of the genera *Synodontis* (*S. schall*), *Bagrus* and *Clarias*, the elephant-snout fish, *Mormyrus*, and the Nile perch, *Lates niloticus*.

An ecologically important distinction can be made between broadly two major groups (Welcomme 1979, 174). *Whitefish* migrate into the main channel of the river at seasons of low water, in order to avoid unfavourable conditions on the floodplain, for example Cyprinidae (carp) and Characidae (tiger-fishes), some Siluridae (catfishes), including *Synodontis schall* and mormyrids (elephant-snout fish). A few species are confined to the river channel at all times and never move onto the floodplain during the seasonal floods. In contrast, *blackfish* demonstrate remarkable resistance to deoxygenated conditions and quite often stay on the floodplain after the seasonal floods have subsided, where they can benefit from the food supplied by terrestrial detritus, for example polypterids (lung fish), some silurids, notably *Clarias*, some mormyrids, and some cichlids, notably *Tilapia*. Small and immature *Synodontis* may be found on the floodplain during the flood season, but adults usually stay in the main channel.

This distinction is important because it affects issues of palatability, and the accessibility and ease of capture of different fish species. For example, the Nile perch, *Lates* is more palatable than catfish of the *Clarias* genus (Boessneck 1988). On the other hand, *Clarias* is easier to catch, because the fish are stranded in shallow pools on the flood plain as the flood waters recede and can easily be caught by spearing, netting or clubbing. In contrast, perch have to be netted from deep water, and are thus a more risky proposition, particularly if crocodiles are in the vicinity. These two groups of fish may also respond differently to environmental changes. Channel fish are likely to be less vulnerable to changes that affect the terrestrial food chain than the blackfish group. It should be noted, however, that the feeding behaviour of some species varies with age. Young schall, for example, are more dependent on food at the base of the trophic pyramid (diatoms, algae and insect larvae) than the older fish, which are mainly fish-eating (Bishai & Gideiri 1965b). The palaeoenvironmental significance of taxonomic representations in archaeological deposits thus needs to take account of accessibility and methods of capture as well as habitat preferences and feeding behaviour.

Egypt is also located on the major migratory route for birds of the Palearctic region. During autumn and spring, huge numbers of birds pass through on route between

Europe and central and southern Africa, such as the common crane, quail and glossy ibis. In addition, the Nile also provides a winter haven for thousands of migratory ducks, waders and many others from practically the whole of the Palearctic region.

This fish and bird fauna provides a potential cornucopia of food. Environments such as these, even at a hunter-gatherer level of organisation, can support sedentary communities with many of the characteristics of storage and social complexity attributed to farming societies and sometimes at higher population densities than neighbouring farmers (Baumhoff 1963; Rowley-Conwy 1983). Indeed, such a precocious development of sedentism and social complexity may already have been in place in parts of the Nile Valley far back in prehistory as early as 18,000 years ago (Close 1996; Hillman 1989).

Archaeological biases

More detailed archaeological examination of the economic basis is hampered in the Egyptian case by a reliance on inadequate, biased or anecdotal evidence, and above all by the lack of well-excavated samples of archaeozoological material from settlement sites that would allow a systematic empirical investigation.

The overwhelming majority of excavated Egyptian sites are tombs rather than settlements. What faunal material there is has usually been recovered haphazardly, and the analysis has been confined to species lists as at Elephantine, the necropolis and the Temple of Satet, Tell el-Dab'a, Tell el-Maskhuta and Karnak (Boessneck 1986; Boessneck and von den Driesch 1982; von den Driesch 1983 and 1986a).

In the Pharaonic period, the main evidence used in discussions of hunting, fishing, diet and animal husbandry is pictorial representations in aristocratic tombs and temples (Darby *et al.* 1977; Daumas 1964; Gaillard 1923; Janssen and Janssen 1989; Keimer 1948; Rzoska 1976; Strouhal 1992; Wilson 1988). These sources of evidence may be misleading as a guide to the subsistence of the population at large as well as being inaccurate or difficult to interpret with respect to taxonomic identification. Recent major publications which have concentrated on the taxa depicted in wall carvings and paintings are vulnerable to subjective and ambiguous accounts of animal usage without benefit of archaeozoological data (Baines and Malek 1984, 16–17; Brewer *et al.* 1994; Houlihan 1986; 1996; Osborn and Osbornova 1998).

For the Roman period, Greek and Coptic papyri provide an important source of information, but here too there are potential biases, since the papyri tend to concern the major taxed crops (Bagnall 1993). Moreover, the Greek papyri refer mainly to the propertied classes, while the Coptic ones refer to the Christian monasteries. Detailed accounts of animal exploitation do not exist,

and assumptions of animal usage are creeping into the literature. Bagnall 1993, 27), for example, has suggested that cereals and legumes were more important in the monastic diet than meat or dairy products on the basis that there was no refrigeration. This is a fallacy since fish and meat from terrestrial animals can be preserved through salting, drying and fermentation. Milk preserves well in the form of fermented dairy products such as yoghurt, while domestic stock need only be slaughtered when wanted. Milk, meat and fish are all preserved at the present day in the Sudan through fermentation (Dirar 1993).

With regard to the analysis of archaeological fish bones, most work in Egypt has concentrated on the prehistoric period (Brewer 1987; Gautier and Van Neer 1989; Van Neer 1986 and 1989; Vermeersch *et al.* 1989). In the Predynastic period, the most detailed information has been obtained from the extensive settlement at Hierakonpolis, 80 km south of Thebes. Here it has been claimed that domestic plants and animals predominate over riverine and desert resources, in spite of the fact that there are large quantities of Nile perch, some well over one metre in length, and large amounts of turtle and crocodile bone (McArdle 1982, 116–121; Brewer 1987, 45–47).

Faunal material from settlement sites in dynastic Egypt is poorly represented with the exception of the 18th-Dynasty site of Tell el-Amarna described below. It is, however, worth noting the recent discovery of a large fish processing plant attached to the bakeries in the pyramid workers' settlement on the Giza plateau (Lehner 1997, 237). Also, documentary evidence from the village of Deir el-Medina, Thebes, relates that four times a month the villagers received great quantities of fish, which were their principal source of nourishment. Twenty fishermen were contracted to supply the workmen and the fish was distributed by rank to forty individuals. The fish supplied included *Tilapia*, *Synodontis*, *Mormyrus* and possibly *Alestes* (Helck 1963, 226–8; Gamer-Wallert 1970, 24–46; Brewer and Friedman 1989, 16).

Fishing is claimed to have played an important role in the local food supply of Roman Egypt (Bowman 1986, 15), although few fish bones have been retrieved from archaeological sites. Scarcely any work has been undertaken on monastic bone in Egypt. Some 8 fish-bone specimens were excavated at the monastery of Phoebammon at Thebes, but no extensive sampling programme was employed (Bachatly 1961). Fishing nets were found at Epiphanius and many fish hooks at Medinet Habu (Terry Wilfong, Michigan State University, pers. comm.). Animal bones have rarely been recovered from archaeological settlement sites, due to lack of excavation, but numerous pig bones along with small amounts of cattle, fish and other animals were recovered from the village of Karanis in the Faiyum (Boak 1933, 88–92).

There is, then, good reason to suppose that fish as a resource and fish-bone material as a source of evidence

have been neglected, and an opportunity to examine that proposition more closely exists at Tell el-Amarna.

TELL EL-AMARNA

Tell el-Amarna is situated on the east bank of the Nile in Middle Egypt near the town of Minya, approximately 304 km south of Cairo in Upper Egypt, halfway between Memphis and Thebes (Fig. 12.1). The plain of Amarna forms a semi-circular bay on the Nile, ringed by limestone cliffs. The site was chosen by the pharaoh Akhenaten for the construction of his cult city, Akhetaten, dedicated to the worship of the Aten, in 1350 BC. There was little arable land on the east bank to sustain the city but crops could be grown on the west bank and supplies could be brought in from beyond. Excavations carried out since 1977 (Kemp 1987, 1984–1989) have yielded large assemblages of bioarchaeological material from a variety of sites and contexts. These include the Pharaonic city (Main City) of the 14th-century BC, the contemporaneous Workmen's Village, and a late Roman monastery (Kom el-Nana) of the 5th to 6th-centuries AD.

The Amarna bone assemblages are of outstanding importance because of the well-preserved bone, the incorporation of a systematic and in depth sampling programme across the excavations ensuring excellent recovery, the short occupation of the archaeological sites set in a virtually unchanged landscape, and a diversity of archaeological deposits covering a time span of nearly 2000 years. In particular, the Pharaonic sites are single-period sites of approximately 30 years duration, and thus bypass the problems, commonly encountered on historical sites, of complex stratigraphic palimpsests spanning centuries or even millennia and posing major problems of residuality. Elsewhere, there have been shifts in the course of the Nile by as much as 3 km since dynastic times, thus obliterating many settlement sites (Bagnall 1993, 6–7; Said 1994, 63). But the Nile in Middle Egypt has barely changed course, ensuring greater

continuity of settlement location and marking this area as exceptionally valuable in interpreting settlement distributions and understanding land-use patterns (Barry Kemp, pers comm).

Both animal bone and plant remains are well preserved

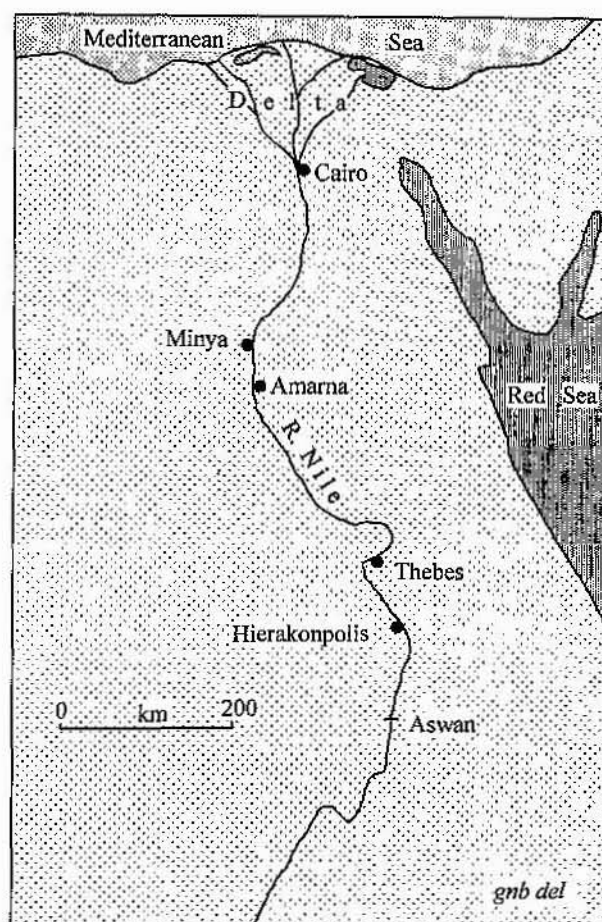


Figure 12.1 Location map of Egypt, showing places mentioned in the text.

		WV %	MC %	RM %
Mormyridae	elephant-snout fish	13.8	7.1	0.4
Characidae	tiger-fish	14	8.5	1.3
Citharinidae	moon-fish	0.1	—	—
Cyprinidae	carp	10.1	7.7	2.5
Clariidae	catfish (<i>Clarias</i>)	4.8	14.5	1.6
Schilbeidae	catfish	—	—	0.3
Bagridae	catfish (<i>Bagrus</i>)	1.4	6.2	5.8
Mochokidae	catfish (<i>Synodontis schall</i>)	31	33	84
Mugilidae	mullet (<i>Mugil</i>)	14.2	7.4	—
Centropomidae	<i>Lates niloticus</i>	0.2	0.8	0.8
Cichlidae	<i>Tilapia</i>	10.5	14.8	3.3
Total		2007	352	3006

Table 12.1 Percentage representation of fish at Amarna according to number of identified bone fragments. WV: Workmen's Village; MC: Main City; RM: Roman Monastery.

and have been subjected to careful sampling and recovery procedures including wet sieving and flotation. A preliminary analysis of the domestic mammalian bone from the 1979 to 1983 excavations of the Workmen's Village was undertaken by Hecker (1984), while Luff examined the butchery of the main domesticates (Luff 1994). The villagers were involved in raising mainly pigs with some goats and cattle, but most of the beef was supplied from the city, most likely from sacrifice in the temples. The use of emmer and barley for cake and bread making is widely documented both by archaeological features and plant remains (Kemp 1994; Samuel 1994).

The mammalian bone assemblages from the Monastery and the Workmen's Village comprise several hundred thousand fragments. In addition to bone of the domestic mammals, there are several thousand well-preserved fragments of fish and bird bone, together with several hundred fragments of eggshell and a small quantity of feathers. The main fish identified so far include the Mochokidae, notably *Synodontis schall*, which dominates both the Workmen's Village and Monastery assemblages (Table 12.1). Mormyridae, Characidae and Mugilidae are also strongly represented at the Workmen's Village but are low in number at the Monastery, where the second most important family represented is the Bagridae. The Main City contrasts with both the other sites in that Clariidae and Cichlidae, especially *Tilapia*, are the second most important groups represented after *S. schall*.

The main bulk of the Workmen's Village bird bone is comprised of a variety of ducks and cormorants which were winter visitors. It is no coincidence that the Great Cormorant, *Phalacrocorax carbo*, figures so predominantly in the avian sample of the Workmen's Village, since one of its favoured prey is mullet, which forms a significant fraction of the fish bone. Butchery marks on the cormorant bones indicate that it was part of the Ancient Egyptian diet. In contrast, the monks were solely reliant on chickens (*Gallus gallus dom.*), rock pigeons (*Columbus livia*) and quail (*Coturnix coturnix*), augmented with the occasional duck and turtle dove.

Here we concentrate on remains of the schall (*Synodontis schall*). This is one of the commonest fish in the Nile today and a popular food fish (Boulenger 1907; Burgess 1989; Poll 1971), and has been the subject of a number of studies of biology and behaviour (Bishai & Gideiri 1965a, 1965b and 1968; Halim and Guma'a 1989; Nawar 1959; Ofori-Danson 1992; Oni *et al.* 1983; Willoughby 1974). It has also been recorded, sometimes in large numbers, from many archaeological sites in the Egyptian Nile Valley and Delta which date from the Predynastic to late Roman periods (Boessneck and von den Driesch 1982; Boessneck *et al.* 1989; Katzman 1990; von den Driesch 1983; 1986a; 1986b; von den Driesch and Boessneck 1985). The animal has distinctive bony head plates and heavily serrated dorsal and pectoral spines

(Fig. 12.2). In addition to its importance as food, the pectoral spines of schall were valued as arrow or spear heads in the Predynastic period and were traded as far afield as the Gaza Strip (Rizkana and Seeher 1989, 73). One isolated specimen has been recorded in a Romano-British deposit (Wheeler and Jones 1989, 129), but the use of pectoral spines as spear tips is not recorded in the Dynastic period. The pectoral spine is a robust and well represented element in the Amarna assemblages and is easily identifiable (Fig. 12.2). It is often complete and can be measured, and also contains a clear record of growth increments that can indicate the age at death of the fish.

In order to maximise the recovery of fish bone, 15 to 20 litres of soil residue were wet sieved through 1mm mesh from sealed and stratified contexts. One hundred residues were examined from rubbish deposits outside the Workmen's Village and 150 residues from midden deposits in the Late Roman monastery. In addition, midden deposits in the Main City excavations produced bone recovered by hand from the trench and by dry-sieving of 20 soil residues through 1 mm mesh.

In a preliminary study, we have selected 317 pectoral

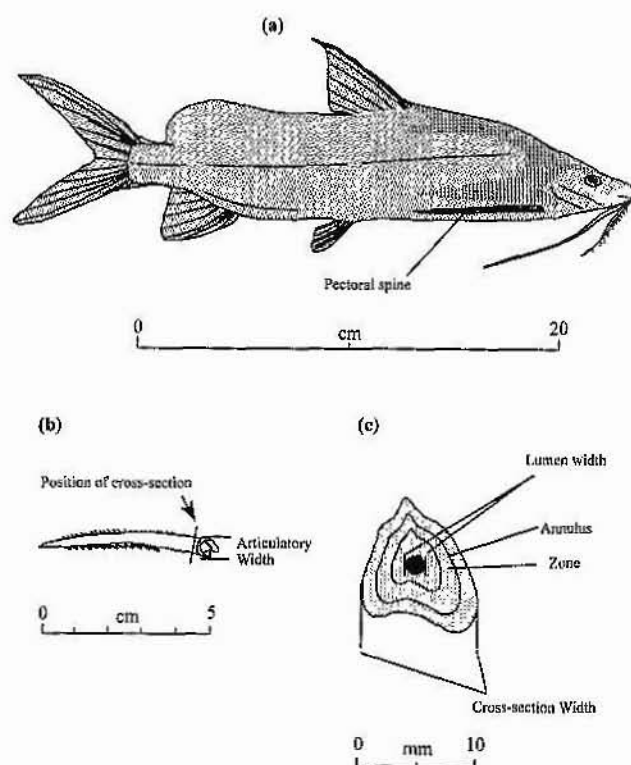


Figure 12.2 (a) Modern schall showing general appearance and location of right-hand pectoral spine (a second is located on the left-hand side); (b) pectoral spine showing measurement of the maximum width of the articulation (ARW); (c) cross-section through pectoral spine showing growth increments, lumen, and measurements used to measure the lumen proportion.

spines for detailed examination, 105 from the Workmen's Village, 192 from the Roman Monastery, and 19 from the Main City. These represent about half the total number of spines recovered and were selected so as to ensure a representative sample of sizes and stratigraphic contexts. Measurements were taken on the maximum width of the articulation (Fig. 12.2). From this sample, 115 specimens were further selected for the production of thin sections and analysis of growth increments. The spines were sectioned transversely (500μ) below the articulation using an Isomet saw. Details of measurements and thin-sectioning techniques are given elsewhere (Luff and Bailey, in press). The samples selected for measurement were necessarily those that have a complete articulation, and we cannot be sure that these are a representative sample of the fish originally caught. However, we note that the sample as a whole includes a wide range of sizes including spines from very small fish <5 cm in length as well as larger specimens. Spines selected for thin-sectioning were chosen for their likely ease of examination rather than as an explicitly representative or random sample. These uncertainties need to be taken into account in the interpretation of results.

SCHALL GROWTH INCREMENTS

Incremental structures are discrete entities of growth commonly recorded in the scales, vertebrae and otoliths of fish. They consist of concentric circuli which vary in their width and are believed to reflect, for the most part, seasonal variations in food supply, with faster growth in the warmer months, and slower growth in the colder months, when fish are less active, feed less and grow more slowly. In principle this banding provides a means of estimating the age at death of a fish and even the season. However, explanations for the formation of growth rings are still subject to uncertainty (Weatherley and Gill 1987, 216), while terminology varies between different workers (cf. Casselman *et al.* 1983; Castanet *et al.* 1993). Following (Castanet *et al.* 1993), we describe the period of fast growth as a *zone*, and that of reduced growth as an *annulus*. Zones appear as relatively wide opaque bands and appear dark in transmitted light (or light in polarised light). Annuli consist of closely spaced circuli which are more translucent than zones and appear white in transmitted light (or dark in polarised light). At the outer edge of the annulus is a line of arrested growth (LAG), which is always very thin (a matter of microns).

Four sorts of uncertainties need to be considered in the interpretation of schall growth increments as evidence of age. The first is the visibility or otherwise of annuli in schall pectoral spines. Some researchers have expressed doubts about the suitability of schall pectoral spines for incremental analysis because of the extremely fatty nature of the bones (Bishai and Gideiri 1965a; Willoughby 1974). However, we have experienced no difficulties in

this regard. Provided the bones are thoroughly degreased, they produce very clear and easily visible structures, and this is true both of archaeological and modern specimens (Figs. 12.3–12.5).

A second problem is the possible presence of false annuli caused by spawning, injury or erratic temperature variation (Brewer 1987, 466; Hashem 1977, 228; Weatherley and Rogers 1978, 56). Spawning takes place in April or May for most fish in the Egyptian Nile (Hassan and el-Salahy 1986) and Brewer (1987) has observed false annuli in specimens of *Clarias* laid down at about this time of year. If these are not distinguished from genuine annuli representing the winter period of reduced growth, the result can be an overestimate of age at death.

It is not clear whether the trigger for spawning is the rise in temperature (Brewer 1987) or the improved food supplies as the river begins to rise and inundate the floodplain with its rich sources of decayed plant matter (Van Neer 1993a and 1993b). Before the construction of the Aswan Dam, the river began to rise in May and June, became fully dilated by the end of September, began subsiding in October and November, and reached its minimum again in December and January (Said 1994, 97). Since water is released from the Aswan Dam in the summer months for agricultural and domestic purposes and for tourism, the Nile continues to replicate the traditional pattern of inundation, albeit in more moderate

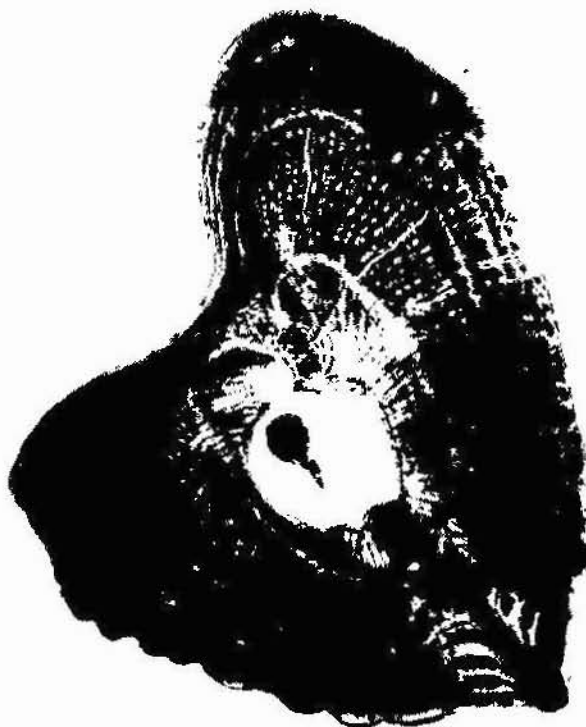


Figure 12.3 Thin section of pectoral spine from a modern schall showing clear alternation of zones and annuli.

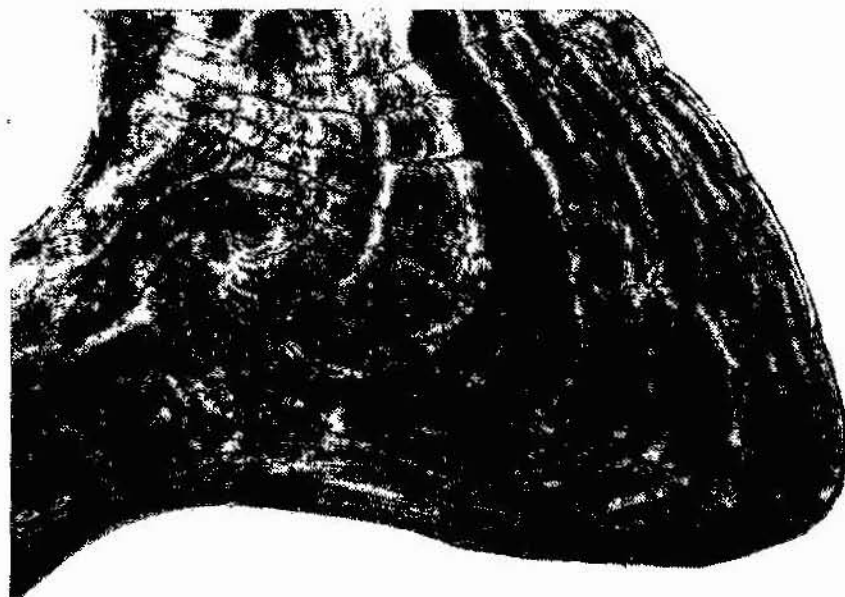


Figure 12.4 Thin section of pectoral spine from the Workmen's village.

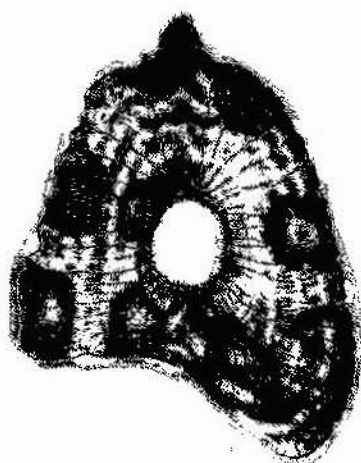


Figure 12.5 Thin section of pectoral spine from the Roman monastery.

form. There is no reason to suppose that spawning behaviour has been significantly altered in timing or frequency by recent changes in the flood regime, or that there is any change in the likelihood of encountering false annuli.

A final problem is that in older fish there may be partial resorption of the bone. This can result in the removal of the first annulus and consequent underestimation of the true age. Märzolf has drawn attention to this problem with the ageing of Channel Catfish, *Ictalurus lacustris punctatus*, seven, eight and nine years of age (Märzolf 1955, 245).

The key to resolving these uncertainties lies in the examination of control samples of modern fish of known dates of capture. Twenty-eight samples of schall, comprising a total of 264 fish, were collected at regular intervals over a 12-month period (April 1996 to March 1997) from Minya, close to Amarna. In addition, 15 schall were collected from the Nile near Cairo close to the Delta Barrage during September 1995. Fish were distinguished by sex, weighed to the nearest gram, and measured by taking the standard length (SL) to the nearest cm. Skeletons were prepared, and pectoral spines were measured and thin-sectioned for examination of the annuli. Resorption of the bone around the lumen (the hollow space which extends along the central axis of the spine) was observed in a number of cases of older-aged fish, especially in the males. The lumen is visible in cross-section as a hole (Figs. 12.2 and 12.3). Where resorption has occurred in modern specimens, the width of the lumen relative to the width of the pectoral bone (the lumen proportion), can be measured in cross-section and shown to be significantly higher than normal (Luff and Bailey in press). Measurement of growth rings in the precaudal vertebrae of the same fish showed that the first year of growth had been removed from the pectoral spines. Accordingly measurement of the lumen proportion has been used to correct age estimates in the archaeological specimens. The modern sample of pectoral spines demonstrates the following features:

- The annuli are clearly visible and only one annulus is laid down each year during the winter period.
- Each annulus is complete around the circumference of the spine.
- Calculations of age made for pectoral spines (and

precaudal vertebrae) from fish of similar lengths are comparable.

- False annuli appear lighter in colour and are incomplete.
- Resorption of bone can be identified and corrected for.

We are therefore confident that we can obtain reliable age estimates from archaeological specimens of schall pectoral spines and compare their size and age characteristics with the modern sample.

INTERPRETATION OF AGE STRUCTURE AND SIZE VARIATION

Theoretical considerations

Fish continue to grow throughout their life span, and in broad terms the larger the individual organism, the older it is. In a simple theoretical model of fisheries exploitation, then, we might expect that a fish population subject to heavy levels of predation would show a relatively small average size compared to an unexploited population, since most fish would be captured when relatively young before they could attain their natural life span and maximum size. Indeed, progressive reduction in the size of organisms recorded at different periods of an archaeological sequence may be interpreted as evidence of increased pressure on food resources by growing human populations (*cf.* Cohen 1977). The reality, however, is more complex. The size attained by fish of a given age depends on their growth rate, and that in its turn depends on the abundance and availability of food, climatic factors that affect the food supply or the feeding behaviour of the fish, and the density of the fish population. Many fish are sensitive to density-dependent factors (Wootton 1990): crowded conditions result in more competition for food and slower growth rates. It follows that fish populations that are subject to increased levels of predation may actually show an *increase* in growth rates. As numerous studies of modern fisheries have indicated (e.g. Nikolskii 1969), and as Swadling (1976) has elegantly demonstrated in an archaeological context, an unexploited population may be expected to show a wide range of age and size classes, a relatively high average size, and relatively slow growth rates. If that population comes under heavier predation pressure, for example because of increased demand for food by a human community, then we should expect to see a narrower range of age classes dominated by younger individuals, a smaller average size for the population as a whole, and increased growth rates. Indeed, age for age, fish in a heavily exploited population may actually be larger than their counterparts in the unexploited population. Conversely, if we find evidence for a reduction in the average size of exploited organisms, but without any reduction in average age, we may hypothesise that some

form of environmental change has occurred that has resulted in reduced growth rates.

Two important points emerge from this discussion. The first is that it is vital in archaeozoological studies to have *independent* data on age and size variation. Studies that use size as a proxy for age, or *vice versa*, cannot discriminate between the different causes of size variation and have to depend on an assumed correlation between age and size that is demonstrably misleading. The second point is that combined information on age and size variation provides a potentially sensitive indicator of varying human pressures on the food supply, of environmental changes, and indeed of possible links between the two.

Results from Amarna

Analysis of the modern sample shows that right and left pectoral spines and the spines of males and females are almost identical in size, and that differential representation of sides or sexes can be eliminated as a possible source of bias in the interpretation of archaeological material (Luff and Bailey *in press*). The size characteristics of the schall in our archaeological and modern samples show clear differences between the Pharaonic, Roman and modern periods (Figs. 12.6 and 12.7). The archaeological samples show a bimodal distribution (apart from the Main City sample, which is very small), with one group of tiny specimens (ARW <5 mm) and a second group of larger fish. At the Roman monastery, these tiny fish are the main component of midden W30. The skeletons are intact and the fish had clearly not been processed for food. It should be noted that small numbers of minute fish spines were recovered from the Workmen's Village (10) and Main City (8), but fragmentation of the articulations precluded their measurement. It is thus possible that small specimens are somewhat under-represented in the Pharaonic samples. We interpret these small specimens as incidental catches acquired, and later discarded, while scooping up *Tilapia* and *Clarias* with baskets or similar containers on the floodplain at the end of the flood season. In the statistical comparison of samples we exclude the W30 midden material from the Roman sample in order to avoid skewing the comparisons. We also use box plots, which emphasise median values and moderate the effect of outliers, and non-parametric tests of significance (Mann-Whitney U and Kolmogorov-Smirnov).

The modern and Pharaonic samples have closely similar size distributions, and this is apparent both from the general plot of size distributions (Fig. 12.6) and the comparison of median values (Fig. 12.7). The Roman sample, however, stands apart with a median value that is significantly lower (0.01 level of probability), even after exclusion of the W30 midden. The Roman sample also shows a broader range of size classes, with a higher coefficient of variation (*V*) of 18.5 (significant at 0.01 level of probability), compared to 11.6 for the Pharaonic and 11.0 for the modern sample. Moreover the Pharaonic

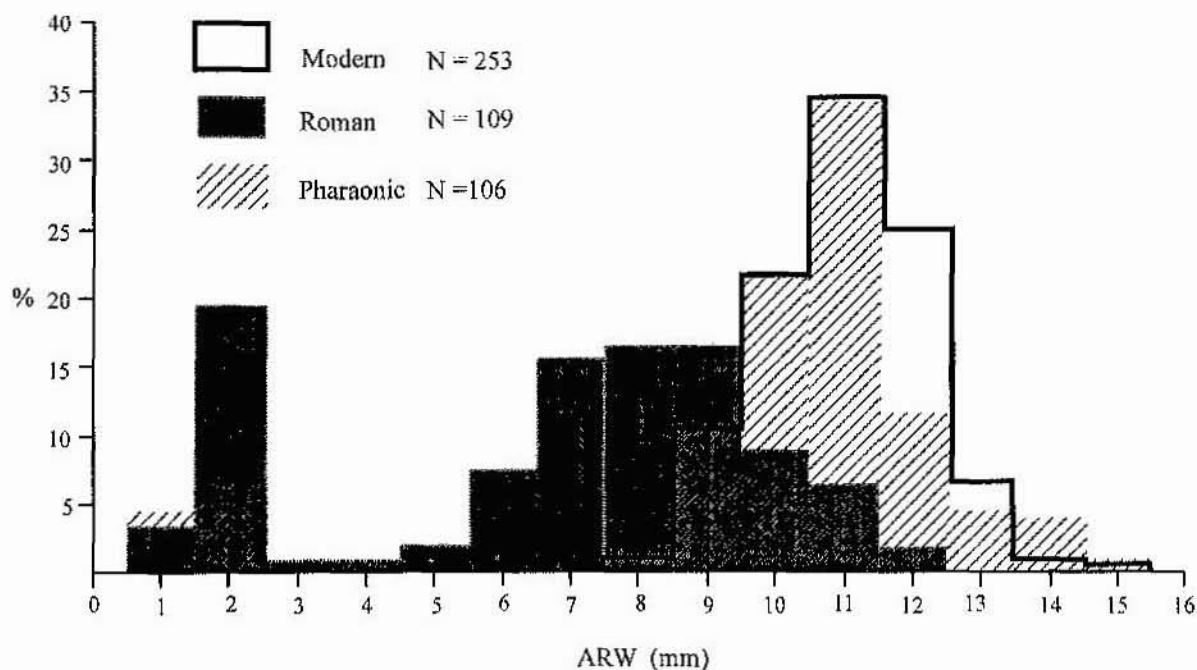


Figure 12.6 Comparison of size histograms of schall pectoral spines from modern samples, and from Pharaonic and Roman contexts at Tell el Amarna. The Roman sample excludes the specimens from the W30 midden.

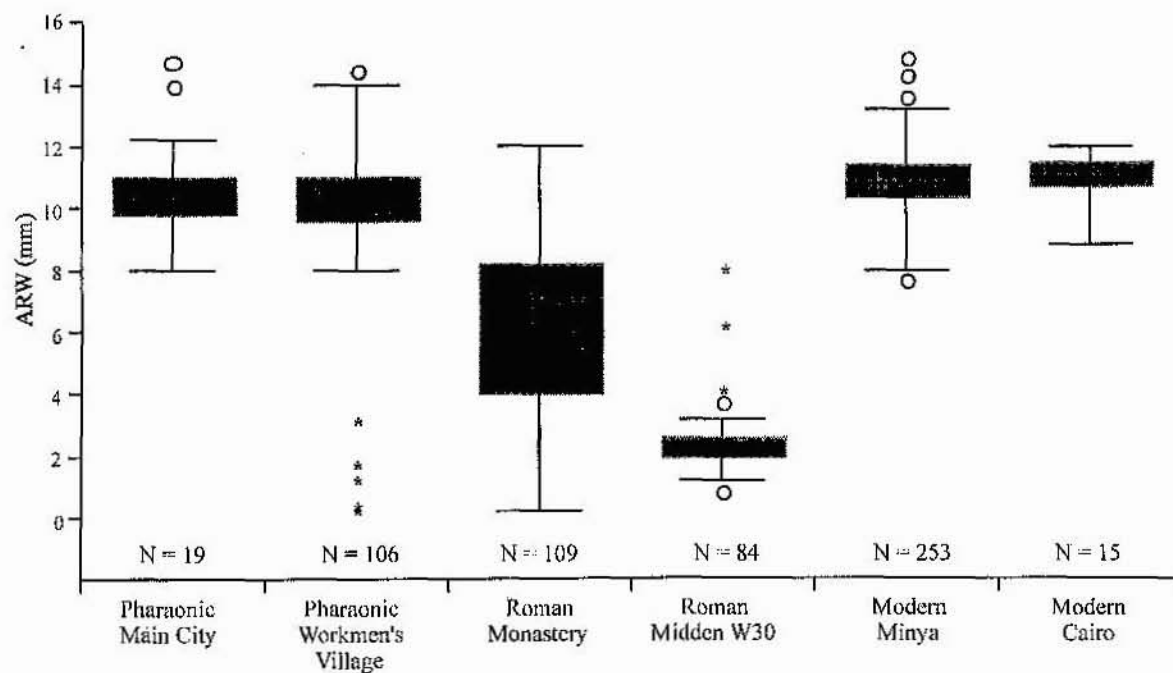


Figure 12.7 Comparison of size measurements of schall pectoral spines from modern, Pharaonic and Roman samples using medians and box and whisker plots. The results from the W30 midden of the Roman monastery are shown for comparison.

and modern distributions both show a positive skew, whereas the Roman sample approximates a normal distribution. All these indications are consistent with the hypothesis that schall in the late Roman period were exploited less intensively than in the Pharaonic or modern period, resulting in slower growth rates and a more mature population with a wider range of age and size classes. In order to test this hypothesis further, however, we need to examine independent data on age and growth rates.

The modern sample shows the youngest age distribution (Fig. 12.8) and the fastest growth rates (Fig. 12.9), as might be expected for an intensively fished population, while the Pharaonic sample shows an age structure dominated by older age classes and the longest tail of aged individuals. Fish of given ages are in general larger in the modern sample than the Pharaonic sample, in particular the five, six and seven year old specimens (significant at 0.05 level of probability). The growth rates of the Roman fish are the slowest of all our samples and produce populations that are smaller by age class (significant at 0.05 level of probability) than their Pharaonic predecessors, in particular the four, five, six, seven, eight and ten year olds (Fig. 12.9). However, if this were due to under-exploitation, as the size data initially led us to expect, we should also expect to find a predominance of old-aged individuals. This is clearly not the case. The age distribution shows a greater predominance of younger age classes, a longer tail of very young specimens and an absence of the very old individuals, compared to the Pharaonic data. The slow growth rates must therefore be the result of some environmental factor affecting the food supply.

To summarise the combined size and age data, the modern sample of schall shows all the characteristics we would expect of a fish population subject to heavy exploitation pressure. It is characterised by faster growth

rates than the other samples, a narrower range of ages, a predominance of young age classes, and a relatively large average size for fish of a given age. It is conceivable that the faster growth rates in the modern sample reflect improved food supplies, but the other age and size characteristics are consistent with heavy exploitation pressure, and we argue that the growth rates reflect the density-dependent effects of competition for food. The Pharaonic samples also show characteristics of an exploited population, though the older age classes and slower growth rates suggest that the pressure of exploitation was lower than at the present day.

The most interesting sample is the Roman material. Here the fish show a lower average age and a slightly narrower range of age classes than the Pharaonic sample (Fig. 12.8). But the growth rates are also significantly lower than either Pharaonic or modern examples (Fig. 12.9), which is why the Roman sample also shows a smaller median size than the others. It could be argued that larger and older-aged specimens are under-represented in the Roman sample because they were removed elsewhere, but we cannot see any reason for supposing that such biases would have had a greater impact on the Roman material in comparison with the other archaeological samples. Certainly our own sampling procedures are likely to have selected for larger specimens for thin-sectioning rather than smaller ones. In any case the growth rates of the younger age classes that are present in the Roman sample are clearly slower than for the other periods, quite independently of any sampling problems with larger specimens. We conclude that schall populations in the Roman period were subject to two effects, relatively heavy exploitation pressure compared to the Pharaonic period, and reduced growth rates. The reduction in growth rates cannot be attributed to density-dependent effects, since this would be inconsistent with the evidence for intensive

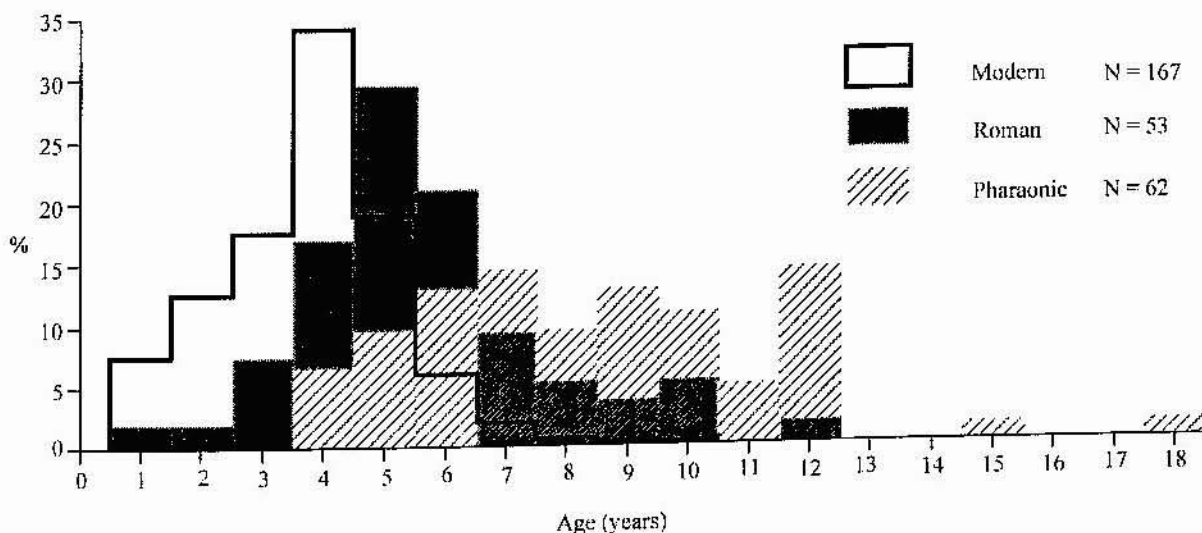


Figure 12.8 Comparison of distributions by age from Pharaonic, Roman and modern contexts.

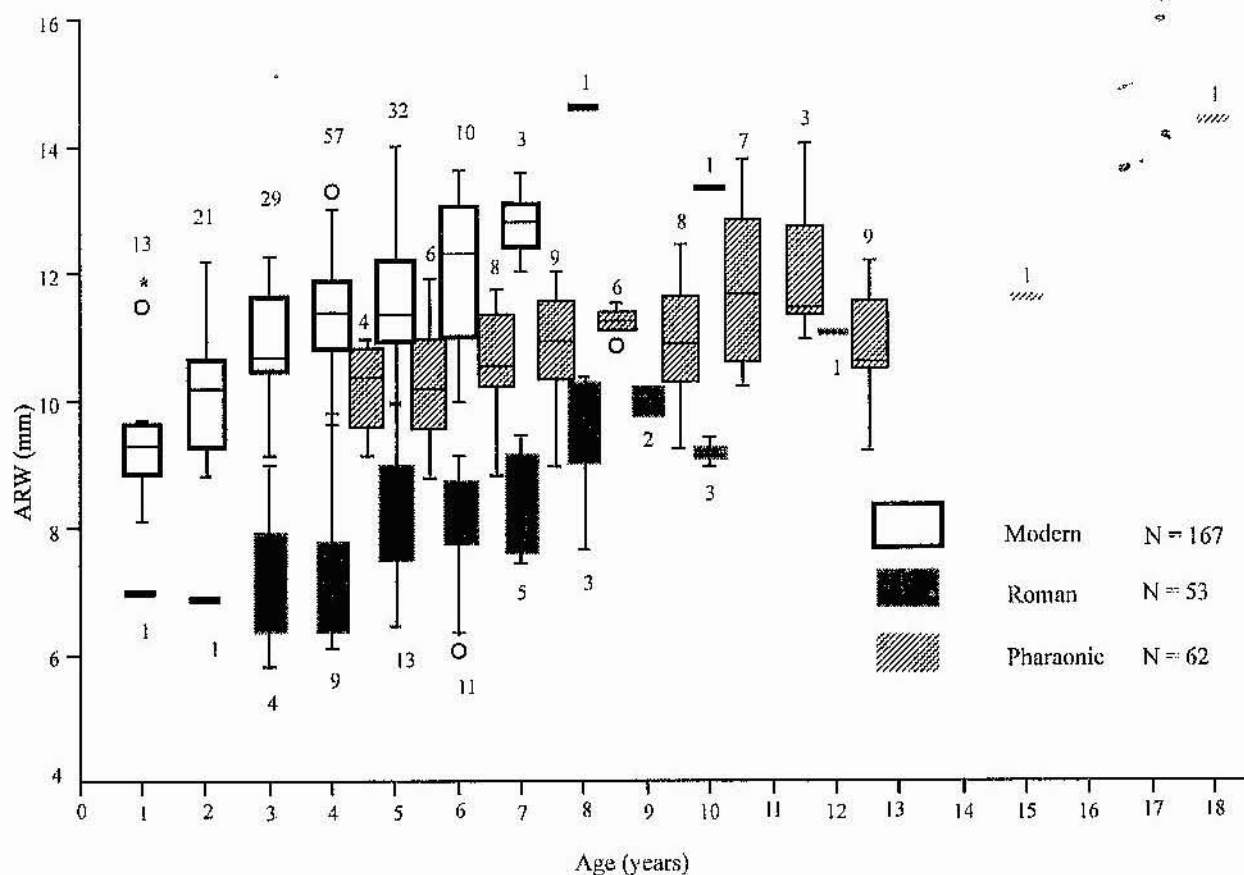


Figure 12.9 Growth rates of schall from Pharaonic, Roman and modern contexts, displayed as size distributions by age class using median values and box and whisker plots. Sample size is indicated above or below each box plot. The Pharaonic plots are displaced to the right for ease of presentation.

fishing, and must therefore be the result of other environmental or climatic change.

There are two principal possibilities for environmental change in the Roman period – we discuss and eliminate some other less plausible possibilities elsewhere (Luff and Bailey in press). The first is a failure of the annual flood because of reduced rainfall in Ethiopia. Low water levels resulting from variations in the intensity and duration of flooding can certainly result in poor growth (Dudley 1974; Kapetsky 1974; Welcomme 1975). Bonneau (1971) has documented the heights of the Nile floods almost annually for the Graeco-Roman period from 261 BC to 299 AD and demonstrated that there were indeed some years when the Nile did not inundate, for example from 168 to 170 AD. Unfortunately there is a dearth of records for the 4th to 6th centuries. High precipitation is claimed for Ethiopia during this period (Fekri Hassan pers. comm; Umer 1992), and Procopius also describes an unusually high Nile flood in the 6th-century AD. Hence it is improbable that the Roman fish were affected by low Nile inundations.

The other possibility is temperature change. Disturbances of a global nature have been well documented for the 6th-century AD. In 536 AD the Praetorian Prefect Cassiodorus wrote to his deputy describing a stupendous calamity whereby the sun was blotted out for the better part of the year, all the crops failed, and the climate turned bitterly cold (Barnish 1992). This particular event has been identified in oaks from the peat bogs of Ireland and also in ice cores from the Greenland ice-cap (Baillie 1991 and 1992), and has been interpreted as the result of a massive volcanic eruption (Keys 1999), or of cometary activity (Asher and Clube 1993, 496; Baillie 1999).

A widespread climatic event of this nature would have caused havoc with crops and livestock and perhaps also reduced the productivity of the floodplain *blackfish* such as *Clarias* and *Tilapia*, placing correspondingly greater pressure on other resources such as the main channel *whitefish* like schall. In this regard it is interesting to observe that the proportion of schall in the Roman deposits at Amarna rises to some 84% in relation to

other fish taxa, compared with about 31–33% in the Pharaonic levels (Table 12.1). This suggests that the Roman inhabitants were more dependent on schall than their predecessors, and this in its turn would have increased the exposure of the schall populations to more intensive exploitation pressure. The normal size distribution of the Roman schall is also consistent with heavy reliance on this species. Positively skewed distributions are more common in exploited populations, and suggest a selective approach to fishing which targets the largest possible specimens above some minimum threshold. The Roman size distribution suggests a less selective targeting which took whatever was available, and this too is consistent with increased pressure on food supplies.

CONCLUSION

We have demonstrated that the pectoral spines of schall contain a clear record of size and age variation and that analysis of size and age structure in comparison with modern samples can illuminate a range of issues including variations in fishing intensity and environmental factors. One of the most interesting results from this analysis is the evidence for an environmental deterioration in the Roman period alongside increased pressure on fishing resources. This in its turn suggests one way in which the aquatic and terrestrial components of the economy may be dynamically interlinked. Reductions in the supply of food from crops and livestock can be compensated for by intensifying fishing activities, and the fish populations in their turn adapt to heavier levels of fishing intensity by adjustments in their age structure and growth rates. Analysis of the growth and size characteristics of the fish bone material from archaeological sites can thus throw light on wider economic interactions and environmental conditions beyond statements about the fishing activity itself. We are still a long way from translating this sort of information into comprehensive statements about the role of fish and other aquatic resources in the wider economy. For one thing we need to examine larger samples of fish bone from Amarna and to place them in the context of the faunal material as a whole. For another, we need to see a similar quality of samples recovered and analysed from other settlements in the Nile Valley and longer time spans before we can reliably generalise from Amarna to the wider geographical context, or place our results into a more complete long-term perspective. Nevertheless, our preliminary results are highly suggestive, and point to a number of hypotheses in need of further testing.

ACKNOWLEDGEMENTS

We gratefully acknowledge the financial support of the Leverhulme Trust. We are also very grateful to Barry Kemp (McDonald Institute, University of Cambridge)

together with the Egypt Exploration Society and the Egyptian Supreme Council of Antiquities for allowing this material to be analysed. In addition, we thank Barry Kemp for providing much valuable discussion and support for the project. We are indebted to Samir Ghoneim (Head of the Fish Research Centre, Suez Canal University, Ismailia), and Ahmed Korkor, who facilitated the collection of modern schall from Minya and enabled a successful ethnographic survey in the area. We also thank Barry Kemp, Muzna Bailey and Marta Moreno-Garcia (Department of Archaeology, University of Cambridge) for assistance with the collection of the modern fish samples near Cairo. We especially thank Wim Van Neer (Musée Royal de L'Afrique Centrale, Tervuren, Belgium), Bob Wootton (Institute of Biological Sciences, University of Wales, Aberystwyth) and Arturo Morales Muniz (Dpto Biología, Universidad Autónoma de Madrid) for critical assessment of the arguments in this paper. We thank Oliver Crimmen of the Fish Section, Zoology Department, British Museum Natural History, for advice and access to the comparative collections and library. We also thank Ian Chaplin (Buehler Krautkramer), Bob Jones (Oceanographic Centre, University of Southampton), Jeremy Skepper (Multi-Imaging Centre, University of Cambridge), Roy Julian (Department of Engineering, University of Cambridge), Sandra Bond (Institute of Archaeology, University College, London) and Glynis Caruana (Earth Sciences, University of Cambridge) for technical assistance. We are grateful to Peter Rowley-Conwy (Department of Archaeology, University of Durham), Tony Leahy (Department of Ancient History and Archaeology, University of Birmingham), Fekri Hassan (Institute of Archaeology, University College, London), Martin Jones (Department of Archaeology, University of Cambridge), Sarah Clackson (Christ's College, University of Cambridge) and Graeme Lawson (McDonald Institute, University of Cambridge) for their interest and support. Photographic assistance was provided by Gwil Owen (Faculty of Archaeology and Anthropology, University of Cambridge), Mike Neville (Institute of Archaeology, University College, London) and Audio Visual Aids (University of Cambridge). Last but not least we thank Simon Goose of the Scientific Periodicals Library, University of Cambridge, for help in locating references.

BIBLIOGRAPHY

- Armstrong, G. J., Van Gerven, D. P., Martin, D. L. and Huss-Ashmore, R. 1984. Effects of nutritional change on the skeletal biology of Northeast African (Sudanese Nubian) populations, pp. 132–146 in Clark, J.D. and Brandt, S.A. (eds.), *From Hunters to farmers: the causes and consequences of food production in Africa*. Berkeley, California: University of California Press.
- Asher, D. J. and Clube, S. V. 1993. An extraterrestrial influence during the current glacial-interglacial. *Quarterly Journal of the Royal Astronomical Society* 34, 48–511.
- Bachatly, C. 1961. *Le monastère de Phoebammon dans le Thebaïde. Tome III: Identifications botaniques, zoologiques et chimiques*. Cairo.

- Bagnall, R. S. 1993. *Egypt in Late Antiquity*. Princeton: Princeton University Press.
- Baillie, M. G. L. 1991. Marking in marker dates: towards an archaeology with historical precision. *World Archaeology* 23, 233-43.
- Baillie, M. G. L. 1992. Dendrochronology and past environmental change, pp. 5-23 in Pollard, A. M. (ed.), *New Developments in Archaeological Science*. Oxford: Oxford University Press.
- Baillie, M. G. L. 1999. *Exodus to Arthur: catastrophic encounters with comets*. London: Batsford.
- Baines, J. and Malek, J. 1984. *Atlas of Ancient Egypt*. Oxford: Phaidon.
- Barnish, S. J. B. 1992. *The Variae of Cassiodorus*. Liverpool: Liverpool University Press.
- Baumhoff, M. A. 1963. Ecological determinants of Aboriginal Californian populations. *University of California Publications in American Archaeology and Ethnology* 49.
- Bishai, H. M. and Gideiri, Y. B. A. 1965a. Studies on the biology of the genus *Synodontis* at Khartoum. 1. Age and growth. *Hydrobiologia* 6, 85-97.
- Bishai, H. M. and Gideiri, Y. B. A. 1965b. Studies on the biology of the genus *Synodontis* at Khartoum. 2. Food and feeding habits. *Hydrobiologia* 26, 98-113.
- Bishai, H. M. and Gideiri, Y. B. A. 1968. Studies on the biology of the genus *Synodontis* at Khartoum. 3. Reproduction. *Hydrobiologia* 31, 193-202.
- Boak, A. E. R. 1933. *Karanis: the temples, coin hoards, botanical and zoological reports, seasons 1924-31*. (University of Michigan Studies, Humanistic Series 30) Ann Arbor: University of Michigan.
- Boessneck, J. 1986. Vogelknochenfunde aus dem alten Ägypten. *Annalen Naturhistorischen Museums in Wien, Series B* 88/89, 323-44.
- Boessneck, J. and Von den Driesch, A. 1982. Studien an subfossilen Tierknochen aus Ägypten. *Münchener Ägyptologische Studien* 40, 1-172.
- Boessneck, J., Von den Driesch, A. and Ziegler, R. 1989. Die Tierreste von Maadi und Wadi Digla, pp. 87-125 in Rizkana I. and Secher, J. (eds.), *Maadi III. The non-lithic small finds and the structural remains of the predynastic settlement*. Mainz: Verlag Philipp Von Zabern.
- Bonneau, D. 1971. *Le fisc et le Nil: incidences des irrégularités de la crue du Nil sur la fiscalité foncière dans l'Égypte grecque et romaine*. Paris: Editions Cujas.
- Borgstrom, G. 1961. *Fish as food. Volume 1: The production, biochemistry and microbiology*. London: Academic Press.
- Boulenger, G. A. 1907. *Fishes of the Nile*. London: Hugh Rees Ltd.
- Bowman, A. K. 1986. *Egypt after the Pharaohs*. London: British Museum Press.
- Brewer, D. J. 1987. Seasonality in the prehistoric Faiyum based on the incremental growth structures of the Nile catfish (*Pisces: Clarias*). *Journal of Archaeological Science* 14, 459-72.
- Brewer, D. and Friedman, R. F. 1989. *Fish and fishing in ancient Egypt, the Natural History of Egypt: volume 11*. Warminster: Aris and Phillips.
- Brewer, D. J., Redford, D. B. and Redford, S. 1994. *Domestic plants and animals: the Egyptian origins*. Warminster: Aris and Phillips.
- Burgess, W. E. 1989. *An atlas of freshwater and marine catfishes: a preliminary survey of the Siluriformes*. Neptune City: T. F. H. Publications Inc.
- Casselman, J. M. and Wilson, N. S. 1983. Glossary in Prince, E. D. and Pulos, L. M. (eds.), *Proceedings of the International Workshop on Age Determination of Oceanic Pelagic Fishes*. NOAA Technical Paper, 58.
- Castanet, J., Francillon-Vieillot, H. and Meunier, F. J. 1993. Bone and individual ageing. *Bone - Bone Growth B* 7, 245-83.
- Close, A. E. 1996. Plus ça change: the Pleistocene-Holocene transition in northeast Africa, pp. 43-60 in Straus, L. G., Eriksen, B. V., Erlandson, J. M. and Yesner, D. R. (eds.), *Humans at the end of the Ice age*. New York: Plenum Press.
- Cohen, M. N. 1977. *The food crisis in prehistory*. New Haven: Yale University Press.
- Darby, W. J., Ghalioungui, P. and Grivetti, L. 1977. *Food: the gift of Osiris, Volumes 1 and 2*. London: Academic Press.
- Daumas, F. V. 1964. Quelques remarques sur les représentations de pêche à la ligne sous l'Ancien Empire. *Bulletin de l'Institut Français d'Archéologie Orientale* 62, 67-85.
- Dirar, H. A. 1993. *The Indigenous Fermented Foods of The Sudan: a Study in African Food and Nutrition*. Wallingford: CAB International.
- Dudley, R. G. 1974. Growth of *Tilapia* of the Kafue floodplain, Zambia: predicted effect of the Kafue Gorge dam. *Transactions American Fisheries Society* 103, 281-91.
- Gaillard, C. 1923. Recherches sur les poissons représentés dans quelques tombeaux Égyptiens de l'Ancien Empire. *Mémoires de l'Institut d'Archéologie Orientale* 51, 1-136.
- Gamer-Wallert, I. 1970. Fische und Fischkulte im alten Ägypten. *Ägyptologische Abhandlungen* 21.
- Gautier, P. and Van Neer, W. 1989. The animal remains from the late Palaeolithic sequence in Wadi Kubbaniya, pp. 119-61 in Wendorf, F., Schild, R. and Close, A. E. (eds.), *Prehistory of Wadi Kubbaniya*. Dallas: Southern Methodist University.
- Greenwood, P. H. 1976. Fish fauna of the Nile, pp. 127-41 in Rzoska, J. (ed.), *The Nile: biology of an ancient river*. The Hague: W. Junk.
- Haas, J. and Harrison, H. 1977. Nutritional anthropology and biological adaptation. *Annual Review of Anthropology* 6, 69-101.
- Halim, A. I. A. and Guma'a, S. A. 1989. Some aspects of the reproductive biology of *Synodontis schall* (Bloch-Schneider, 1801) from the White Nile near Khartoum. *Hydrobiologia* 178, 243-51.
- Hashem, M. T. 1977. Age determination and growth studies of *Bagrus bayad* in the Nozha-Hydrodrome. *Bulletin of the Institute of Oceanography and Fisheries, Arab Republic of Egypt* 7, 225-45.
- Hassan, K. A. and el-Salahy, M. B. 1986. Effect of seasonal variation on weight composition and gross chemical composition of three Nile fish species. *Bulletin of the Faculty of Sciences, Assiut University* 15, 89-99.
- Hecker, H. 1984. Preliminary report on the faunal remains, pp. 154-64 in B. Kemp (ed.), *Amarna Reports I*. London: Egypt Exploration Society.
- Helck, W. 1963. *Materialien zur Wirtschaftsgeschichte des Neuen Reiches, III*. Wiesbaden: Akademie der Wissenschaften und der Literatur in Mainz in Kommission bei Franz Steiner.
- Hillman, G. C. 1989. Late Palaeolithic plant foods from Wadi Kubbaniya in Upper Egypt: dietary diversity, infant weaning, and seasonality in a riverine environment, pp. 207-39 in Harris, D. R. and Hillman, G. C. (eds.), *Foraging and Farming*. London: Unwin-Hyman.
- Houlihan, P. F. 1986. *The Birds of Ancient Egypt: the natural History of Ancient Egypt: volume 1*. Warminster: Aris and Phillips.
- Houlihan, P. F. 1996. *The Animal World of the Pharaohs*. London: Thames and Hudson.
- Janssen, R. and Janssen, J. 1989. *Egyptian Household Animals*. Princes Risborough, Buckinghamshire: Shire Egyptology.
- Kapetsky, J. M. 1974. Growth, mortality and production of five fish species of the Kafue River floodplain, Zambia. Unpublished PhD dissertation, University of Michigan.
- Katzman, L. 1990. *Tierknochenfunde aus Elephantine in Oberägypten (Grabungsjahre 1976 bis 1986/1987): Vögel, Reptilien, Fische und Molluske*. Unpublished PhD Dissertation, München.
- Keimer, L. 1948. Quelques représentations rares des Poissons Égyptiens remontant à l'époque Pharaonique. *Bulletin de l'Institut d'Égypte* 29, 263-74.
- Kemp, B. J. 1984-1989. *Amarna Reports*. London: Egypt Exploration Society.

- Kemp, B. J. 1987. The Amarna Workmen's Village in retrospect. *Journal of Egyptian Archaeology* 73, 21–50.
- Kemp, B. J. 1994. Food for an Egyptian City, pp. 133–58 in Luff, R. M. and Rowley-Conwy, P. (eds.), *Whither Environmental Archaeology*. Oxford: Oxbow Books.
- Keys, D. 1999. *Catastrophe*. London: Century Books.
- Lehner, M. 1997. *The Complete Pyramids*. London: Thames and Hudson.
- Luff, R. M. 1994. Butchery at the Workmen's Village, Tell el-Amarna, Egypt, pp. 158–70 in Luff, R. M. and Rowley-Conwy, P. (eds.), *Whither Environmental Archaeology*. Oxford: Oxbow Books.
- Martin, D. L., Armelagos, G. J. and Henderson, K. A. 1989. The persistence of nutritional stress pp. 163–187 in Huss-Ashmore, R. and Katz, S. H. (eds.), *Northeastern African (Sudanese Nubian) populations in African food systems in crisis. Food and Nutrition in history and anthropology volume 7, part one: Microperspectives*. New York: Gordon and Breach.
- Marzolf, R. C. 1955. Use of pectoral spines and vertebrae for determining age and rate of growth of the Channel catfish. *Journal of Wildlife Management* 19, 243–49.
- McArdle, J. 1982. Preliminary report on the predynastic fauna at the Hierakonpolis project, pp. 110–15 in Hoffman, M. (ed.), *The Predynastic of Hierakonpolis*. Cairo: The Egyptian Studies Association Publication.
- Moseley, M. E. 1975. *The maritime foundations of Andean civilization*. Menlo Park: Cummings.
- Moseley, M. E. 1992. Maritime foundations and multilineal evolution: retrospect and prospect. *Andean Past* 3, 5–42.
- Nawar, G. 1959. On the fecundity of the Nile catfish *Synodontis schall* (Bloch-Schneider, 1801). *Sudan Notes and Records* 40, 139–40.
- Nikolskii, G. V. 1969. *Theory of Fish Population Dynamics*, translated by J.E.S. Bradley. Edinburgh: Oliver & Boyd.
- Ofori-Danson, P. K. 1992. Ecology of some species of catfish *Synodontis* (Pisces: Mochokidae) in the Kpong Headpond in Ghana. *Environmental Biology of Fishes* 35, 49–61.
- Oni, S. K., Olayemi, J. Y. and Adeboye, J. D. 1983. Comparative physiology of three ecologically distinct freshwater fishes, *Alestes nurse* Ruppell, *Synodontis schall* Bloch and Schneider and *Tilapia zillii* Gervais. *Journal of Fish Biology* 22, 105–109.
- Osborn, D. J. and Osbornova, J. 1998. *The Mammals of Ancient Egypt*. Warminster: Aris and Phillips.
- Poll, M. 1971. Révision des *Synodontis* africains (Famille Mochokidae). *Annales de Musée Royal de l'Afrique Centrale, Sciences Zoologiques* 191.
- Rizkana, I. and Seeher, J. 1989. Maadi III. The non-lithic small finds and the structured remains of predynastic settlement. Mainz: Philipp von Zabern.
- Rowley-Conwy, P. A. 1983. Sedentary hunters: the Ertebolle example, pp. 111–26 in Bailey, G.N. (ed.), *Hunter-Gatherer Economy in Prehistory*. Cambridge: Cambridge University Press.
- Royce, W. F. 1996. *Introduction to the Practice of Fishery Science*. London: Academic Press.
- Rzoska, J. (ed.) 1976. *The Nile: biology of an ancient river*. The Hague: W. Junk.
- Said, R. 1994. The Nile and modern Egypt; life and death on a river. *Newsletter of the American Research Center in Egypt* 164, 10–17.
- Samuel, D. 1994. Cereal food processing in Ancient Egypt: a case study of integration, pp. 153–58 in Luff, R. and Rowley-Conwy, P. (eds.), *Whither Environmental Archaeology* Oxford: Oxbow.
- Santley, R. S. and Rose, S. K. 1979. The political economy of core-periphery systems, pp. 17–43 in Schortman, E. M. and Urban, P. A. (eds.), *Research, power and interregional interaction*. New York: Plenum Press.
- Seddek, A. L., Salem, D. A., El-Sawi Nagwa, M. and Zaky, Z. M. 1996. Cadmium, lead, nickel, copper, manganese and fluorine levels in River Nile fish in Assiut Governorate, Egypt. *Wien. Tierärztliche Monatsschrift* 83, 374–7.
- Strouhal, E. 1992. *Life in ancient Egypt*. Cambridge: Cambridge University Press.
- Swadling, P. 1976. Changes induced by human exploitation in prehistoric shellfish populations. *Mankind* 10, 156–62.
- Tosi, M. 1986. The emerging picture of prehistoric Arabia. *Annual Review of Anthropology* 15, 461–90.
- Umer, M. 1992. *Paléoenvironnements et paléoclimatologie des derniers millénaires en Éthiopie*. Contribution palynologique. Unpublished PhD Université Aix-Marseille 3.
- Van Neer, W. 1986. Some notes on the fish remains from Waddi Kubbaniya (Upper Egypt, late Palaeolithic), pp. 103–13 in Brinkhuizen, D. C. and Clason, A. T. (eds.), *Fish and Archaeology*. (British Archaeological Reports International Series 294). Oxford: British Archaeological Reports.
- Van Neer, W. 1989. Fishing along the prehistoric Nile, pp. 49–56 in Krzyzaniak, L. and Kobusiewicz, M. (eds.), *Late Prehistory of the Nile Basin and the Sahar*. Poznan: Polish Academy of Sciences.
- Van Neer, W. 1993a. Limits of incremental growth in seasonality studies; the example of the Clariid pectoral spines from the Byzantine-Islamic site of Apamea (Syria; sixth to seventh century AD). *International Journal of Osteoarchaeology* 3, 119–27.
- Van Neer, W. 1993b. Daily growth increments on fish otoliths as seasonality indicators on archaeological sites: the *Tilapia* from Late Palaeolithic Makhadma in Egypt. *International Journal of Osteoarchaeology* 3, 241–48.
- Vermeersch, P., Paulissen, E. and Van Neer, W. 1989. The late Palaeolithic Makhadma site: environment and subsistence, pp. 87–114 in Krzyzaniak, L. and Kobusiewicz, M. (eds.), *Late Prehistory of the Nile Basin and the Sahara*. Poznan: Polish Academy of Sciences.
- Von den Driesch, A. 1983. Some archaeozoological remarks on fishes in Ancient Egypt, pp. 86–110 in Clutton-Brock, J. and Grigson, C. (eds.), *Animals and Archaeology: 2. Shell Middens, Fishes and Birds*. (British Archaeological Reports International Series 183) Oxford: British Archaeological Reports.
- Von den Driesch, A. 1986a. Fische im alten Ägypten – Eine osteoarchäologische Untersuchung. *Documenta Naturae* 34.
- Von den Driesch, A. 1986b. Der Fiederbartwels, *Synodontis schall*, als Lieferant von Pfeilspitzen im alten Ägypten. *Annalen des Naturhistorischen Museums in Wien, Series B* 88/89, 128–31.
- Von den Driesch, A. and Boessneck, J. 1985. *Die Tierknochenfunde aus der neolithischen Siedlung von Merimde-Benisalame am westlichen Nildelta*. München.
- Weatherley, A. H. and Rogers, S. C. 1978. Some aspects of age and growth, pp. 52–73 in Gerking, S.D. (ed.), *Ecology of freshwater fish production*. London: Blackwell Scientific Publications.
- Weatherley, A. H. and Gill, H. S. 1987. *The biology of fish growth*. London: Academic Press.
- Welcomme, R. L. 1975. The fisheries ecology of African floodplains. Committee for Inland Fisheries of Africa technical paper No. 3. Food and Agriculture Organisation of the United Nations). Rome, pp. 1–51.
- Welcomme, R. L. 1979. *Fisheries Ecology of Floodplain Rivers*. London and New York: Longmans.
- Wheeler, A. and Jones, A. K. G. 1989. *Fishes*. Cambridge: Cambridge University Press.
- WHO (World Health Organization) 1972. Evaluation of mercury, lead, cadmium, and the food additives amaranth, diethylpyrocyanate and actyl gallate. WHO, 16th Rep. Joint FAO/WHO Expert Committee on Food Additives, *World Health Organisation Technical Report service* 505.
- Willoughby, N. G. 1974. *The ecology of the genus Synodontis in Lake Kaingi, Nigeria*. Unpublished PhD thesis. University of Southampton.
- Wilson, H. 1988. *Egyptian food and drink*. Princes Risborough: Shire Egyptology.
- Wootton, R. J. 1990. *Ecology of Teleost fishes*. Fish and Fisheries Series 1. London: Chapman and Hall.